073-08-13 - Monday

Hydrology & Agricultural Mateorology

Q1) Define Hydrology? with water balance equation.

⇒ Hydrology means the science of water. It is the science that deals with the occurrence, circulation & distribution of water of the earth & earth's atmosphere. As a branch of earth science, it is concerned with the water in streams & lakes, rainfall & snowfall, snow & ice on land & water occuring below the earth's surface in the pores of the soil & rocks.

Water balance equation can be given as,

$$I - O = \Delta S$$

where I = Inflow

O = outflow &

ΔS = change in storage.

Q2) Brifly describe the hydrological cycle with its components.

⇒ Water occurs on the earth in all its three states i.e solid, liquid & gaseous. Evaporation of water from water bodies such as oceans & lakes, formation & movement of clouds, rain & snowfall, streamflow and groundwater flow are some examples of the dynamic aspects of water. The various aspects of the water related to the earth in terms of cycle is water cycle

The various components of hydrologic cycle can be describe as.

a) Precipitation:
After the cloud is formed, they are condense & fall onto the land as a rain is precipitation.

b) Evaporation:
When the heat energy is provided to the ocean or sea by means of solar radiation, the water thus evaporate & moves above the ocean level.

c) Transpiration:
Different vegetation sends a portion of the water from under ground surface back to the atmosphere through the process of transpiration.

d) Infilteration
A portion of water that reaches the ground enters the earth's surface through the process of infilteration.

e) Runoff
The portion of the precipitation which by a variety of paths above or below the surface of the earth reaches the stream channel is known as runoff. Once it enters a stream channel, runoff becomes stream flow.

Q3) Write down the scope of hydrological study & its application in agricultural engineering field.

→ The scope of hydrological study & its application in agricultural engineering field are discussed below.

a) Water resource projects.
Hydrology finds its greatest application in the design and operation of water resources in engineering projects. The hydrological study of a project should necessarily proceed structural & other detailed design studies. It involves the collection of relevent data & analysis of the data by applying the principle & theories of hydrology to seek solution to practical problems.

b) Drinking water supply.
There is a great scope of hydrology in drinking water supply. Drinking water should be distributed throughout the place through water pump, water pipes, etc, from the rivers or reservoirs.

c) Irrigation & drainage engineering
In irrigation projects & hydraulics structure, there finds a great scope while designing irrigation canal & projects.

d) water power
Nepal is a developing country & is in developing stage so there is comming many hydropower where it has great scope.

e) Navigation
Navigation is the field of study that focuses on the process of monitoring & controlling the movement of a craft or vehicle from one place to another.

f) Recreational uses.

g) Bridge, dam, reservoirs, etc.

Application of hydrology in agricultural engineering field.
→ Designing irrigation schemes & managing agricultural productivity.
→ Determining the water-balance of a region.
→ Determining the agricultural waterbalance
→ Designing dams for water supply or hydroelectric power generation.
→ providing drinking water.
→ Designing sewers & urban drainage system.
→ Mitigating & predicting flood, landslide & drought risk.

Q4) Briefly describe the important of hydrological study in the context of Nepal.

⇒ Hydrology means science of water. Hydrology is the branch of earth science that deals with the occurance, circulation & distribution of water of the earth atmosphere. As a branch of earth science, it is concerned with the water in streams, lakes, rainfall & snowfall, snow & ice on the land ~~w~~ and water occurring below the earth surface in the pore of soil & rocks.

Nepal is in the developing stage, so there is a great importance of hydrological study.

In Nepal, hydrological study finds its greatest application in the design & operation of water-resources engineering projects, such as those for i) irrigation ii) water supply iii) flood control iv) water power v) Navigation.

i) irrigation

There involves numerous project on irrigation such as designing of canal, dams, reservoirs, etc. In doing so, there will be efficient, economic & effective

ii) Water supply

on supplying of water, there is great importance

of hydrological study. As hydrology is the science of water, it controls & managed how to supply water from one place to another.

iii) Flood control
Hydrological study plays a vital role in controlling the flood. It determines how much ppt^n occurs, runoff, storage & rainfall. By knowing these one can determine the solution of control for flood.

iv) water power
There ~~a~~ are ~~pr~~ number of projects involves in hydropower water there ~~is~~ a great role of hydrological study. To designing hydropower, one have to know the discharge, velocity, rainfall, runoff, etc. These can only be done by good hydrologists.

v) Navigation
There is a great importance of hydrological study in the field of Navigation. Navigation is the field of study that focuses on the process of monitoring & controlling the movement of a craft or vehicle from one place to another by a ship, aircraft or a spaceship involves under Navigation. As a whole, hydrological study is very much important in the country like Nepal, to develop the whole nation

Numerical Problems.

1) The mass curve of an isolated strom in a 500ha watershed is as follows.

Time from start (h)	0	2	4	6	8	10	12	14	16	18
cumulative rainfall (cm)	0	0.8	2.6	2.8	4.1	7.3	10.8	11.8	12.4	12.6

If the direct runoff produced by the strom is measured at the outlet of the watershed as 0.340 Mm^3, estimate the ϕ-index of the strom & duration of rainfall excess.

Sol^n. Given, Total rainfall $= \Sigma \Delta P_i$ or, $\Sigma\, i \times \Delta t$

where, $i = \Delta P / \Delta t$ = rate of rainfall

ΔP = amount of rainfall in time Δt

Time (hr)	cumulative rainfall (cm)	Incremental rainfall in each time interval (ΔP) (cm)	$i = \Delta P / \Delta t$
0	0	0	–
2	0.8	0.8 − 0 = 0.8	0.4
4	2.6	2.6 − 0.8 = 1.8	0.9
6	2.8	2.8 − 2.6 = 0.2	0.1
8	4.1	4.1 − 2.8 = 1.3	0.65
10	7.3	7.3 − 4.1 = 3.2	1.6
12	10.8	10.8 − 7.3 = 3.5	1.75
14	11.8	11.8 − 10.8 = 1.0	0.5
16	12.4	12.4 − 11.8 = 0.6	0.3
18	12.6	12.6 − 12.4 = 0.2	0.1

$\Sigma \Delta P = 12.6$

$$\text{Runoff, } Q = \Sigma(i-\phi)\Delta t$$

Trial I

Assume the runoff occurs from the begining of the rainfall & hence $t_e = 18$ hours

$$\phi\text{-index, } \phi = \frac{\text{amount of infilteration}}{\text{time}}$$

$$= \frac{\text{total rainfall} - \text{total runoff}}{\text{time}}$$

$$= \frac{P_e - Q}{t_e}$$

where, P_e = total precipitation during which runoff take

Q = total amount of runoff

t_e = effective time at which runoff take place.

Now,

$$\text{Runoff, } Q = 0.34 \times 10^6 m^3 \text{ over } 500ha$$

$$= \frac{0.34 \times 10^6 m^3}{500 \times 10^4 m^2} = 0.068m = 6.8cm$$

$$\therefore \phi = \frac{P_e - Q}{t_e} = \frac{12.6 - 6.8}{18} = 0.322 cm/hr$$

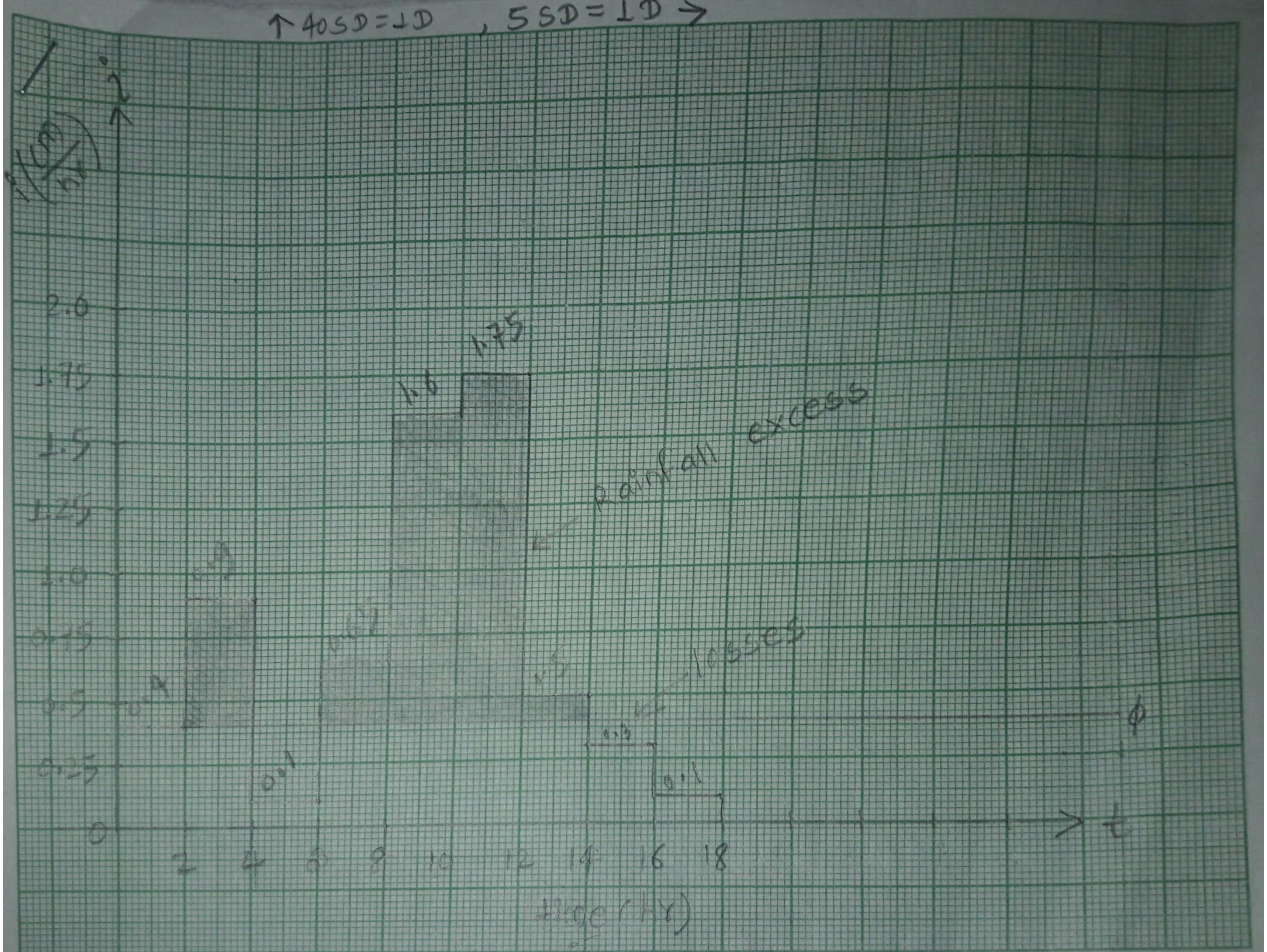
check

$$Q = \begin{bmatrix} (0.4-0.322)+(0.9-0.322)+(0.1-0.322)+(0.65-0.322)+(1.6-0.322) \\ +(1.75-0.322)+(0.5-0.322)+(0.3-0.322)+(0.1-0.322) \end{bmatrix} \times 2$$

$$= [0.078 + 0.578 + 0 + 0.328 + 1.278 + 1.428 + 0.178 + 0 + 0] \times 2$$

$$= 7.736 \text{ cm} \neq 6.8 \text{ cm}$$

So, Trial II


↑ 40SD = 1D , 5SD = 1D →
i (cm/hr)
2.0
1.75
1.5
1.25
0.5
0.25
0
1.6
1.75
Rainfall excess
losses
0.1
0.1
φ
t
2
4
6
8
10
12
14
16
18
time (hr)

page.99 जतिवटा zero आयो त्यो घटा हटाउने.

$t_e = 18 - 6 = 12$ hr

$P_e = 12.6 - 0.2 - 0.6 - 0.2 = 11.6$

$Q = 6.8$ cm

$\therefore \phi = \dfrac{P_e - Q}{t_e} = \dfrac{11.6 - 6.8}{12} = 0.4$ cm/hr

Check

$$Q = \begin{bmatrix} (0.4-0.4) + (0.9-0.4) + (0.1-0.4) + (0.65-0.4) + (1.6-0.4) + \\ (1.75-0.4) + (0.5-0.4) + (0.3-0.4) + (0.1-0.4) \end{bmatrix} \times 2$$

$$= [0 + 0.5 + 0 + 0.25 + 1.2 + 1.35 + 0.1 + 0 + 0] \times 2$$

$= 6.8$ cm checked

Here, calculated runoff is equal to the given runoff so, ϕ = infiltration rate / ϕ-index $= 0.4$ cm/hr

Ans. $\left.\begin{array}{l}\phi = 0.4 \text{ cm/hr.} \\ t_e = 10 \text{ hours}\end{array}\right\}$

3.19) 2) The mass curve of an isolated strom over a watershed is given below.

Time from start (h)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
cumulative rainfall (cm)	0	0.25	0.50	1.10	1.60	2.60	3.50	5.70	6.50	7.30	7.70

If the strom produced a direct runoff of 3.5cm at the

outlet of the watershed, estimate the ϕ-index of the storm and duration of rainfall excess.

Sol^n^ Pulses of uniform time duration $\Delta t = 0.5h$ are considered

Time from start (h)	cumulative rainfall (cm)	Incremental rainfall in each time interval, ΔP (cm)	$i = \Delta P / \Delta t$
0	0	0	0 –
0.5	0.25	0.25 − 0 = 0.25	0.5
1.0	0.50	0.50 − 0.25 = 0.25	0.5
1.5	1.10	1.10 − 0.50 = 0.60	1.2
2.0	1.60	1.60 − 1.10 = 0.50	1
2.5	2.60	2.60 − 1.60 = 1.0	2
3.0	3.50	3.50 − 2.60 = 0.9	1.8
3.5	5.70	5.70 − 3.50 = 2.20	4.4
4.0	6.50	6.50 − 5.70 = 0.8	1.6
4.5	7.30	7.30 − 6.50 = 0.8	1.6
5.0	7.70	7.70 − 7.30 = 0.4	0.8
		$\Delta P = 7.70$	

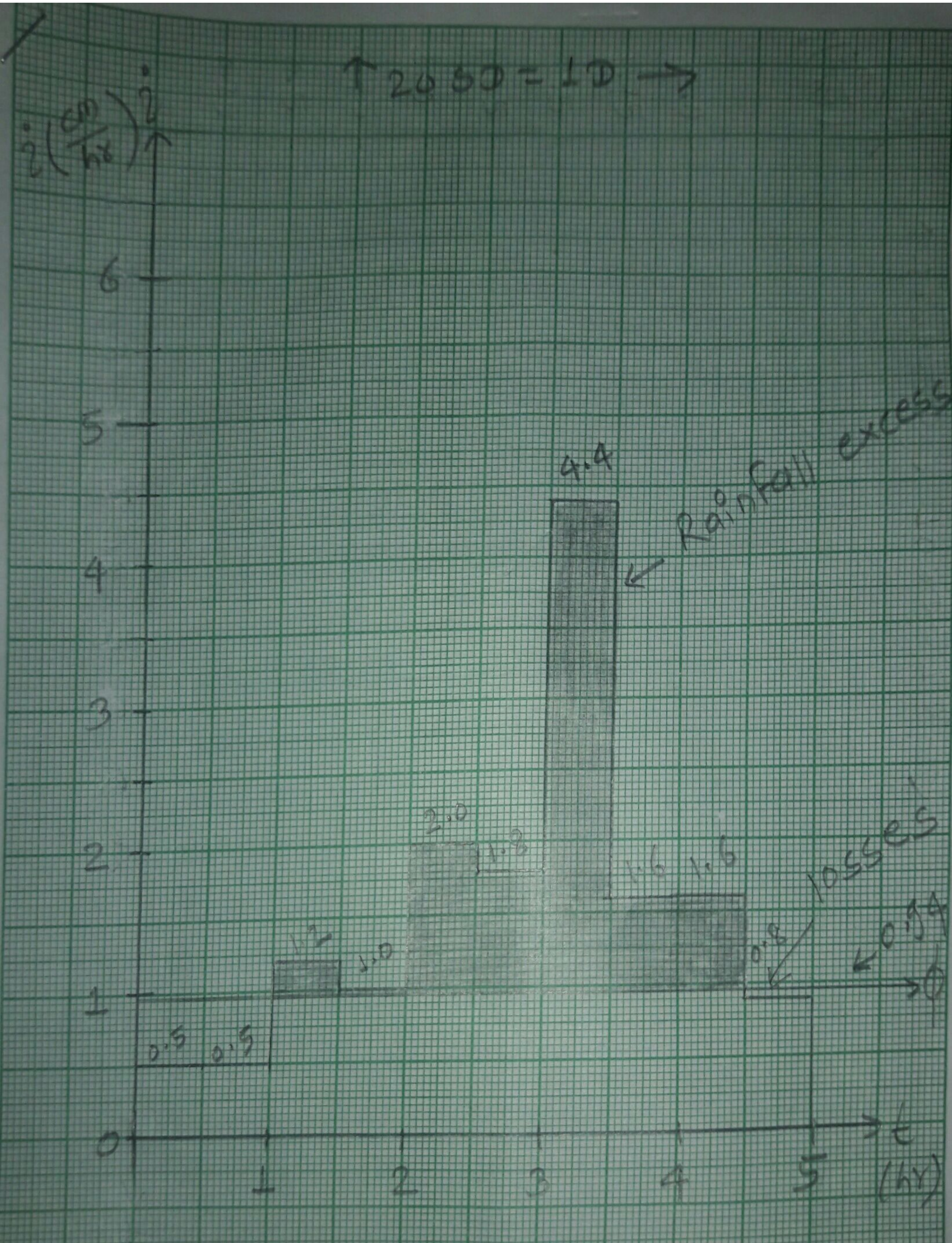
Trial I

Assume the ~~rainfall~~ runoff occurs from the begining of the rainfall & hence $t_e = 5\ hr$

$P_e = 7.70$ cm (Given)

$Q = 3.5$ cm (Given)

$$\phi = \frac{P_e - Q}{t_e} = \frac{7.70 - 3.5}{5} = 0.84\ cm/hr$$



2080 = 1D
i (cm/hr)
6
5
4
3
2
1
0
4.4
Rainfall excess
2.0
1.8
1.6
1.6
1.2
1.0
0.8
losses
0.5
0.5
0.9
φ
1
2
3
4
5
t (hr)

check

$$Q = \begin{bmatrix} (0.5-0.84)+(0.5-0.84)+(1.2-0.84)+(1-0.84)+(2-0.84)+ \\ (1.8-0.84)+(4.4-0.84)+(1.6-0.84)+(1.6-0.84)+(0.8-0.84) \end{bmatrix} \times 0.5$$

$$= [0+0+0.36+0.16+1.16+0.96+3.56+0.76+0.76+0] \times 0.5$$

$$= 16.08\ cm \neq 3.5\ cm$$

so, Trial II

$$P_e = 7.70 - 0.25 - 0.25 - 0.4 = 6.8\ cm$$

$$Q = 3.5\ cm$$

$$t_e = 5 - 1.5 = 3.5\ hr$$

$$\therefore \phi = \frac{P_e - Q}{t_e} = \frac{6.8 - 3.5}{3.5} = 0.94\ cm/hr$$

check

$$Q = \begin{bmatrix} (0.5-0.94)+(0.5-0.94)+(1.2-0.94)+(1-0.94)+(2-0.94)+ \\ (1.8-0.94)+(4.4-0.94)+(1.6-0.94)+(1.6-0.94)+(0.8-0.94) \end{bmatrix} \times 0.5$$

$$= [0+0+0.26+0.06+1.06+0.86+3.46+0.66+0.66+0] \times 0.5$$

$$= 3.5\ cm/hr \text{ checked}$$

Here, calculated runoff is equal to the given runoff

so, $\phi = \phi\text{-index} = \cancel{3.5\ cm/hr}\ 0.94\ cm/hr$

Ans. $\phi\text{-index} = \overset{0.94}{\cancel{3.5}}\ cm/hr$

$t_e = 3.5$ hours

Q) For a given basin, the following are the infilteration ~~cap~~ capacity rates at various time intervals after the begining of the strom. Make a plot of the f-curve & establish an equation of the form developed by Horton. Also determine the total rain and the excess rain (runoff).

Time (min)	Precipitation rate (cm/hr)	Infilteration capacity (cm/hr)
1	5.0	3.9
2	5.0	3.4
3	5.0	3.1
4	5.0	2.7
5	5.0	2.5
6	7.5	2.3
8	7.5	2.0
10	7.5	1.8
12	7.5	1.54
14	7.5	1.43
16	2.5	1.36
18	2.5	1.31
20	2.5	1.28
22	2.5	1.25
24	2.5	1.23
26	2.5	1.22
28	2.5	1.20
30	2.5	1.20

1 cm = 1 f , 1 cm = 2 min

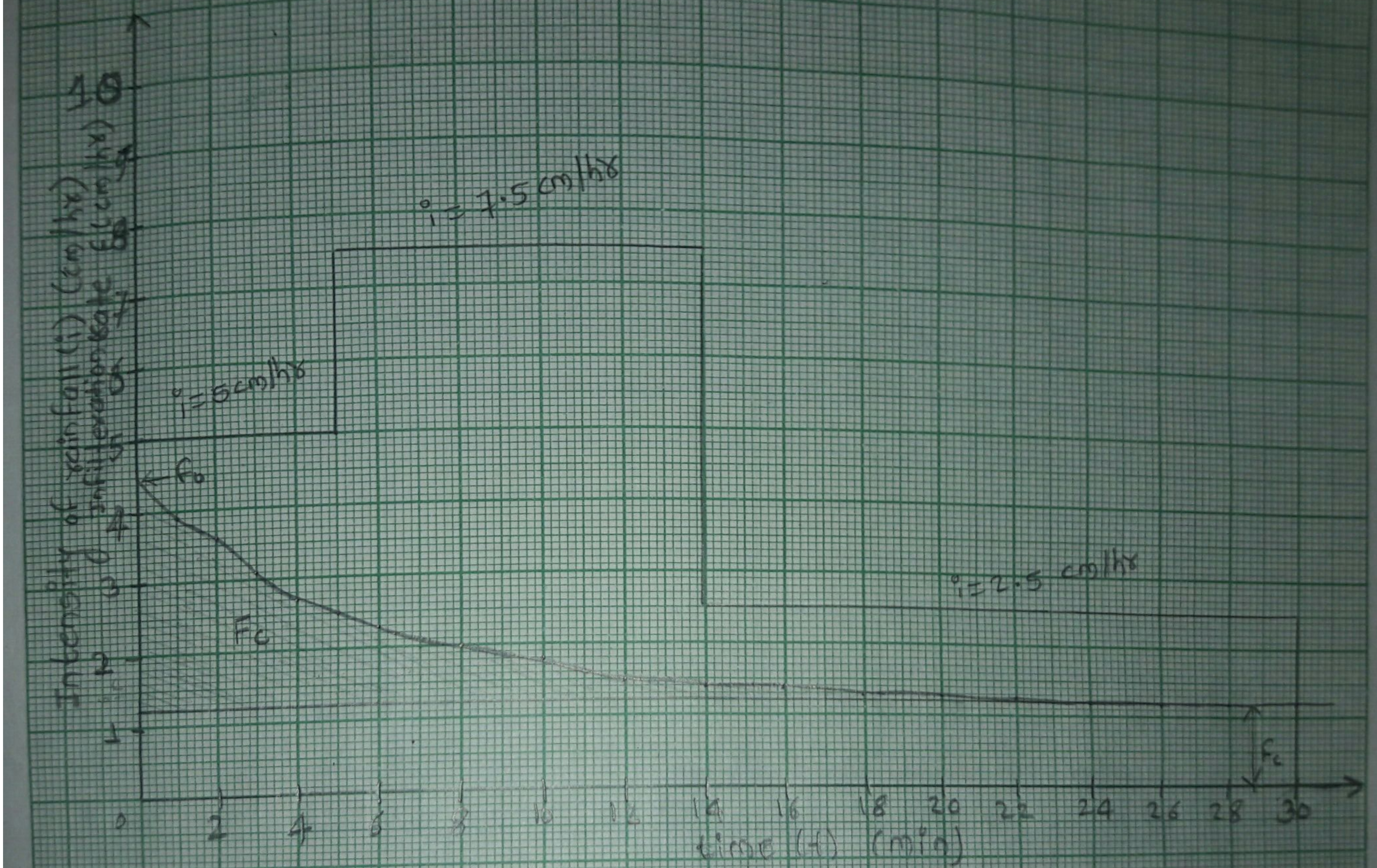


Fig. Infilteration loss & net rain

Sol^n The precipitation & infilteration rates versus time are plotted as in a graph.

In the Hortons equation, the Horton's constant

$$k = \frac{f_0 - f_c}{F_c}$$

In graph, one largest square curve $= \frac{1\ cm}{hr} \times 2\ min = \frac{1\ cm}{hr} \times \frac{1\ hr}{60\ min} \times 2\ min$

$= 1/30\ cm$

From graph,

We get,

$F_c = 8.5$ sq. units (shaded portion)

Rainfall $(P) = 66.25$ sq. units

Area under f curve $(F_p) = 26$ sq. units

Now, Excess rain $P_{net} = P - F_p$

$= (66.25 - 26)$ sq. units

$= 40.25$ sq. units

$= (40.25) \times 1/30$ cm

$= 1.34$ cm

Total rain $(P) = 66.25$ sq. units

$= (66.25) \times 1/30$ cm

$= 2.21$ cm

Also, for Horton equation,

$F_c = 8.5$ sq. units

$= 8.5 \times 1/30\ cm = 0.28\ cm$.

$\therefore K = \frac{f_0 - f_c}{F_c} = \frac{(4.5 - 1.2)\ cm/hr}{0.28\ cm} = 11.79\ hr^{-1}$

$\therefore$ The Horton's equation is,

$$f = f_c + (f_0 - f_c)e^{-kt}$$

$$= 1.2 + (4.5 - 1.2)e^{-11.79t}$$

$$\therefore f = 1.2 + \frac{3.3}{e^{11.79t}}$$

Q) For a small catchment, the infilteration rate at the begining of the rain was observed to be 90 mm/hr & decreased exponentially to a constant rate of 8 mm/hr after 2½ hr. The total infilteration during 2½ hr was 50 mm. Develop the Hordon's equation for the infilteration rate at any time $t < 2½$ hr.

Soln. Given, $f_0 = 90\ mm/hr$

$f_c = 8\ mm/hr$

Now, $F_c = 50 - 8 \times 2\frac{1}{2}$

$= 50 - 8 \times 2.5$

$= 30\ mm$

Then, Hordon's constant, $K = \frac{f_0 - f_c}{F_c}$

$= \frac{90 - 8}{30}$

$= 2.73\ hr^{-1}$ //

& Horton's equation is given as,

$$f = f_c + (f_0 - f_c)e^{-kt}$$

$$= 8 + (90 - 8)e^{-2.73t}$$

i.e $f = 8 + 82e^{-2.73t}$, f in mm/hr, t in hr

Q) A 24-hour strom occurred over a catchment of 1.8 km² area and the total rainfall observed was 10 cm. An infilteration ~~curve prepared~~ capacity curve prepared had the initial infilteration capacity of 1 cm/hr & attained a constant value of 0.3 cm/hr after 15 hours of rainfall with a Horton's constant $K = 5\ hr^{-1}$. An IMD pan installed in the catchment indicated a decrease of 0.6 cm in the water level (after allowing for rainfall) during 24 hours of its operation. Other losses were found to be negligible. Determine the runoff from the catchment. Assume a pan coefficient of 0.7.

Sol^n Given, $f_0 = \cancel{10\ mm\ cm/hr}\ 1\ cm/hr$

$f_c = 0.3\ cm/hr$

$K = 5\ hr^{-1}$

Now,

$$f = f_c + (f_0 - f_c)e^{-kt}$$

$$= 0.3 + (1.0 - 0.3)e^{-5t}$$

$$= 0.3 + \frac{0.7}{e^{5t}}$$

Now, Horton's equation is given as,

$$F_p = \int_0^{24} \cancel{(f_c + (f_0 - f_c)} \, f\,dt$$

$$= \int_0^{24} \left(0.3 + 0.7\, e^{-5t}\right) dt$$

$$= \left[0.3t + \frac{0.7}{-5e^{5t}}\right]_0^{24}$$

$$= \left[0.3 \times 24 - \frac{0.7}{5e^{5\times 24}}\right] - \left[0 - \frac{0.7}{5e^{0}}\right]$$

$$= 7.2 + \frac{0.7}{5}\left(1 - \frac{1}{e^{120}}\right)$$

$$= 7.34 \text{ cm}$$

$\therefore$ Runoff $= P - F_p - E$

$= 10 - 7.34 - (0.6 \times 0.7)$

$= 2.24$ cm

And, volume of runoff from the catchment

$$= \frac{2.24 \cancel{\text{cm}}}{100} \text{m} \times (1.8 \times 10^{6})\,\text{m}^2$$

$$= 40320 \text{ m}^3$$

S3.20) Q) In a 140 min strom of following rates of rainfall were observed in successive 20-min intervals: 6.0, 6.0, 18.0, 13.0, 2.0, 2.0 & 12.0 mm/hr. Assuming the ϕ index value as 3.0 mm/hr & an initial loss of 0.8 mm, determine the total rainfall, net rainfall & W-index for the strom.

Soln Given,

1	2	3	$4 = 2 - \phi$	$5 = 4 \cdot 3$
Time (hr)	Rainfall intensity (mm/hr)	Rainfall depth (mm)	effective rainfall intensity (mm/hr)	excess rainfall (mm)
$20/60 = 1/3$	6.0	2.0	6.0−3.0 = 3.0	1.0
$40/60 = 2/3$	6.0	2.0	6.0−3.0 = 3.0	1.0
$60/60 = 1$	18.0	6.0	18.0−3.0 = 15.0	5.0
$80/60 = 4/3$	13.0	4.33	13.0−3.0 = 10.0	3.33
$100/60 = 5/3$	2.0	0.67	2.0−3.0 = 0	0
$120/60 = 2$	2.0	0.67	2.0−3.0 = 0	0
$140/60 = 7/3$	12.0	4.0	12.0−3.0 = 9.0	3.0

Total rainfall = 19.67 mm Total ex. rainfall = 13.33 mm

Also, given, ϕ-index = 3.0 mm/hr

initial losses (I_a) = 0.8 mm

From table, duration of excess rainfall = 140-20-20

= 100 min

= $5/3$ hr.

Now,

we have,

$$w\text{-index} = \frac{P - R - I_a}{t_e} = \frac{P-R}{t_e} - \frac{I_a}{t_e}$$

$$= \phi\text{-index} - \frac{I_a}{t_e}$$

$$\therefore W\text{-index} = 3 - \frac{0.8}{5/3}$$
$$= 2.52 \text{ mm/hr.}$$

5.3.21) Q) The mass curve of rainfall of duration 100min is given below. If the catchment had an initial loss of 0.6 cm and ϕ-index of 0.6 cm/hr, calculate the total surface runoff from the catchment.

Time from start of rainfall (min)	0	20	40	60	80	100
cumulative rainfall (cm)	0	0.5	1.2	2.6	3.3	3.5

Sol^n Given, initial loss (I_a) = 0.6 cm

ϕ-index = 0.6 cm/hr

time (min)	cumulative rainfall (cm)	incremental rainfall (ΔP)	~~incremental~~ rainfall intensity ~~rainfall/hr~~ (ΔP/hr) (cm/hr)	excessive rainfall intensity (cm/hr)	excess rainfall (cm)
20	0.5	0.5	~~0.167~~ 1.5	0.9	0.3
40	1.2	1.2−0.5=0.7	~~0.233~~ 2.1	1.5	0.5
60	2.6	2.6−1.2=1.4	~~0.467~~ 4.2	3.6	1.2
80	3.3	3.3−2.6=0.7	~~0.233~~ 2.1	1.5	0.5
100	3.5	3.5−3.3=0.2	~~0.067~~ 0.6	0	0

$\therefore$ excess rainfall = 0.3 + 0.5 + 1.2 + 0.5

= 2.5 cm

i.e. Total surface runoff = 2.5 cm.//

5.3.22) 8) An isolated 3-h strom occurred over a basin in the following fashion.

% of catchment area	ϕ-index (cm/hr)	Rainfall (cm)		
		1^{st} hour	2^{nd} hour	3^{rd} hour
20	1.00	0.8	2.3	1.5
30	0.75	0.7	2.1	1.0
50	0.50	1.0	2.5	0.8

Estimate the runoff from the catchment due to the ~~sol^n~~ strom.

sol^n For 20% catchment area.

Time (hr)	Rainfall (cm)	Rainfall intensity (cm/hr)	effective Rainfall intensity (cm/hr)	Excess rainfall (cm)
1	0.8	0.8	$0.8-1=0$	0
2	2.3	2.3	$2.3-1.0=1.3$	1.3
3	1.5	1.5	$1.5-1.0=0.5$	0.5

Total runoff = 1.8 cm

ϕ - index = 1.00 cm/hr.

For 30% catchment area.

Time (hr)	Rainfall (cm)	Rainfall intensity (cm/hr)	effective rainfall intensity (cm/hr)	Excess rainfall (cm)
1	0.7	0.7	$0.7-0.75=0$	0
2	2.1	2.1	$2.1-0.75=1.35$	1.35
3	1.0	1.0	$1.0-0.75=0.25$	0.25

Total runoff = 1.60 cm

ϕ - index = 0.75 cm/hr

For 50% catchment area

Time (hr)	Rainfall (cm)	Rainfall intensity (cm/hr)	effective rainfall intensity (cm/hr)	excess rainfall (cm)
1	1.0	1.0	$1.0 - 0.5 = 0.5$	0.5
2	2.5	2.5	$2.5 - 0.5 = 2.0$	2.0
3	0.8	0.8	$0.8 - 0.5 = 0.3$	0.3

Total runoff = 2.8 cm

ϕ-index = 0.5 cm/hr

Now,

$$\text{Total runoff} = \frac{A_1R_1 + A_2R_2 + A_3R_3}{A_1 + A_2 + A_3}$$

$$= \frac{20 \times 1.8 + 30 \times 1.6 + 50 \times 2.8}{20 + 30 + 50}$$

$$= \frac{224}{100}$$

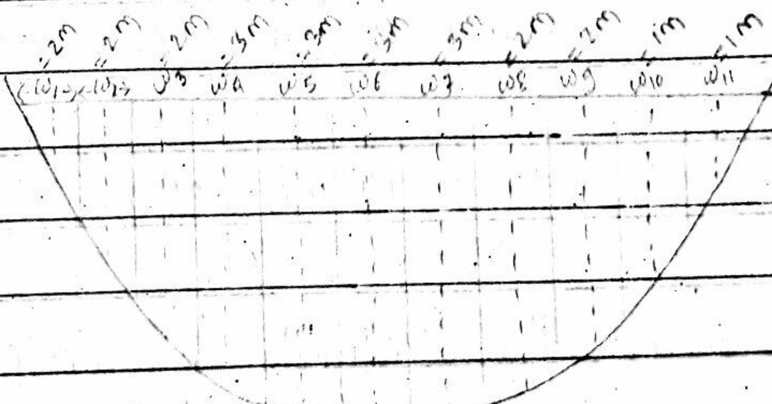
$$= \underline{\underline{2.24 \text{ cm}}}$$

54.3) Q) The following are the data obtained in a stream gauging operation. A current meter with a calibration equation $V = (0.32N + 0.032)\,m/s$, where N = revolutions per second was used to measure the velocity at 0.6 depth. Using the mid-section method, calculate the discharge in the stream.

distance from rt. bank(m)	0	2	4	6	9	12	15	18	20	22	23	24
Depth (m)	0	0.50	1.10	1.95	2.25	1.85	1.75	1.65	1.50	1.25	0.75	0
No. of revolutions	0	80	83	131	139	121	114	109	92	85	70	0
observation Time(s)	0	180	120	120	120	120	120	120	120	120	150	0

soln Given, $V = (0.32N + 0.032)\,m/s$

Distance from rt bank(m)	0	2	4	6	9	12	15	18	20	22	23	24
Depth (m)	0	0.50	1.10	1.95	2.25	1.85	1.75	1.65	1.50	1.25	0.75	0
No. of revolution (R)	0	80	83	131	139	121	114	109	92	85	70	0
observation time(s)	0	180	120	120	120	120	120	120	120	120	150	0
$N = R/t$	0	0.44	0.69	1.09	1.16	1.00	0.95	0.91	0.77	0.71	0.47	0
$V = 0.32N + 0.032$	~~0.032~~	0.1728	0.2528	0.3808	0.4032	0.352	0.336	0.3232	0.2784	0.2592	0.1824	~~0.032~~



For the first & last segment,

Average width $(\bar{w}) = \left\{\dfrac{\left(w_1 + \frac{w_2}{2}\right)^2}{2w_1}\right\}$

$= \left\{\dfrac{\left(2 + \frac{2}{2}\right)^2}{2\times 2}\right\} = 2.25\,m$

For the calculation of width,

$$b_1 = \frac{(\omega_1 + \omega_2/2)^2}{2\omega_1} = \frac{(2+2/2)^2}{2\times 2} = 2.25m$$

$$b_2 = \frac{(\omega_2 + \omega_3)}{2} = \frac{(2+2)}{2} = 2m$$

$$b_3 = \omega_3/2 + \omega_4/2 = 2/2 + 3/2 = 2.5\ m$$

$$b_4 = \omega_4/2 + \omega_5/2 = 3/2 + 3/2 = 3m$$

$$b_5 = \omega_5/2 + \omega_6/2 = 3/2 + 3/2 = 3m$$

$$b_6 = \omega_6/2 + \omega_7/2 = 3/2 + 3/2 = 3m$$

$$b_7 = \omega_7/2 + \omega_8/2 = 3/2 + 2/2 = 2.5m$$

$$b_8 = \omega_8/2 + \omega_9/2 = 2/2 + 2/2 = 2m$$

$$b_9 = \omega_9/2 + \omega_{10}/2 = 2/2 + 1/2 = 1.5m$$

$$b_{10} = \frac{(\omega_{10}/2 + \omega_{11})^2}{2\omega_{11}} = \frac{(1/2 + 1)^2}{2\times 1} = 1.125m$$

Since the velocity is measured at 0.6 depth, the measured velocity is the average velocity at the vertical $(\bar{v})$

The calculation of discharge by the mid-section method is shown in tabular form below.

a	b	c	d	e	f = b×c×e
distance from right water edge (m)	Average width ($\bar{w}$)(m)	Depth(y) (m)	N/s = Rev/sec.	Velocity ($\bar{v}$) (m/s)	segmental discharge (ΔQ) (m^3/s)
0	0	0	0	–	0.0000
2	2.25	0.50	0.44	0.1728	0.1944
4	2	1.10	0.69	0.2528	0.55616
6	2.5	1.95	1.09	0.3808	1.8564
9	3	2.25	1.16	0.4032	2.7216
12	3	1.85	1.00	0.3520	1.9536
15	3	1.75	0.95	0.3360	1.764
18	2.5	1.65	0.91	0.3232	1.3332
20	2	1.50	0.77	0.2784	0.8352
22	1.5	1.25	0.71	0.2592	0.4860
23	1.125	0.75	0.47	0.1824	0.1539
24	0	0	0	–	0.0000

sum = 11.85446 m^3/s.

Discharge in the stream = 11.85446 m^3/sec.

2073-11-2 - monday.

Q) The following data was collected for a stream at a gauging station compute the discharge by,

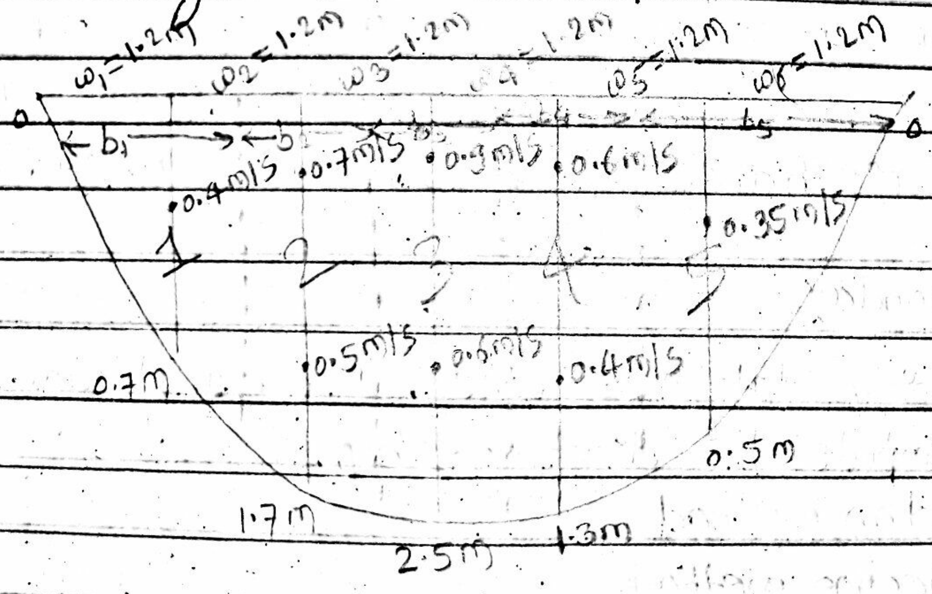
i) mid section method

ii) mean section method.

Distance from one end of water surface (m)	Depth of water (m)	velocity m/s.		
		at 0.6d	at 0.2d	at 0.8d
0	0	-	-	-
1.2	0.7	0.4	-	-
2.4	1.7	-	0.7	0.5
3.6	2.5	-	0.9	0.6
4.8	1.3	-	0.6	0.4
6.0	0.5	0.35	-	-
7.2	0	-	-	-

soln: i) mid section method.

no. of segment = no. of depth = 5



Now, for the calculation of width,

considering the area of both side of the bank.

$$b_1 = \frac{(w_1 + w_2/2)^2}{2w_1} = \frac{(1.2 + 1.2/2)^2}{2 \times 1.2} = 1.35m$$

$b_2 = w_2/2 + w_3/2 = 1.2/2 + 1.2/2 = 1.2\,m$

$b_3 = w_3/2 + w_4/2 = 1.2/2 + 1.2/2 = 1.2\,m$

$b_4 = w_4/2 + w_5/2 = 1.2/2 + 1.2/2 = 1.2\,m$

$$b_5 = \frac{(w_6 + w_5/2)^2}{2w_6} = \frac{(1.2 + 1.2/2)^2}{1.2} = 1.35\,m$$

Then, average velocities of each section is given by

$U_1 = U$ at $0.6d = 0.4\,m/s$

$$U_2 = U \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.7 + 0.5}{2} = 0.6\,m/s$$

$$U_3 = U \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.9 + 0.6}{2} = 0.75\,m/s$$

$$U_4 = U \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.6 + 0.4}{2} = 0.5\,m/s$$

$U_5 = U$ at $0.6d = 0.35\,m/s$

& the given ~~dep~~ average depths of each section is,

$d_1 = 0.7\,m$

$d_2 = 1.7\,m$

$d_3 = 2.5\,m$

$d_4 = 1.3\,m$

$d_5 = 0.5\,m$

so, calculating the ~~discharge as~~ total discharge as sum of discharge from each section.

i.e $Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$

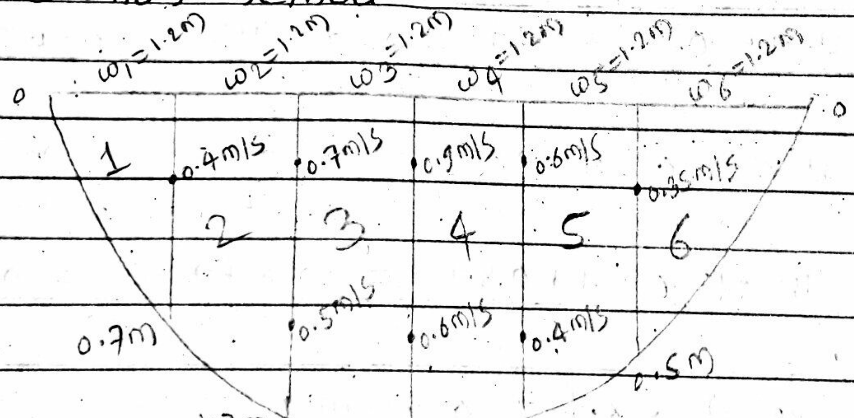
$= b_1 d_1 V_1 + b_2 d_2 V_2 + b_3 d_3 V_3 + b_4 d_4 V_4 + b_5 d_5 V_5$

$= 1.35 \times 0.7 \times 0.4 + 1.2 \times 1.7 \times 0.6 + 1.2 \times 2.5 \times 0.75 + 1.2 \times 1.3 \times 0.5 + 1.35 \times 0.5 \times 0.35$

$\therefore Q = 4.86825\ m^3/sec.$

Hence, required discharge is $Q = 4.86825\ m^3/sec.$

ii) mean section method.



no. of segment = no. of depth + 1 = 5+1 = 6

Now, calculation of average depth of each segment

$d_1 = \left(\frac{0+0.7}{2}\right)m = 0.35m$

$d_2 = \left(\frac{0.7+1.7}{2}\right)m = 1.2m$

$$d_3 = \left(\frac{1.7+2.5}{2}\right)m = 2.1 m$$

$$d_4 = \left(\frac{2.5+1.3}{2}\right)m = 1.9 m$$

$$d_5 = \left(\frac{1.3+0.5}{2}\right)m = 0.9 m$$

$$d_6 = \left(\frac{0.5+0}{2}\right) = 0.25 m$$

Then, calculation of average velocities of each segment

$$v_1 = \frac{0+0.4}{2} = 0.2 m/s$$

$$v_2 = \frac{0.4+\left(\frac{0.7+0.5}{2}\right)}{2} = 0.5 m/s$$

$$v_3 = \frac{\left(\frac{0.7+0.5}{2}\right)+\left(\frac{0.9+0.6}{2}\right)}{2} = 0.675 m/s$$

$$v_4 = \frac{\left(\frac{0.9+0.6}{2}\right)+\left(\frac{0.6+0.4}{2}\right)}{2} = 0.625 m/s$$

$$v_5 = \frac{\left(\frac{0.6+0.4}{2}\right)+(0.35)}{2} = 0.425 m/s$$

$$v_6 = \frac{0.35+0}{2} = 0.175 m/s.$$

So, calculating total discharge as sum of discharge from each section,

i.e $Q = Q_1+Q_2+Q_3+Q_4+Q_5+Q_6$

$= w_1d_1v_1 + w_2d_2v_2 + w_3d_3v_3 + w_4d_4v_4 + w_5d_5v_5 + w_6d_6v_6$

$= 1.2 \times 0.35 \times 0.2 + 1.2 \times 1.2 \times 0.5 + 1.2 \times 2.1 \times 0.675 +$
$1.2 \times 1.9 \times 0.625 + 1.2 \times 0.9 \times 0.425 + 1.2 \times 0.25 \times 0.175$

$\therefore Q = 4.44415\ m^3/s.$

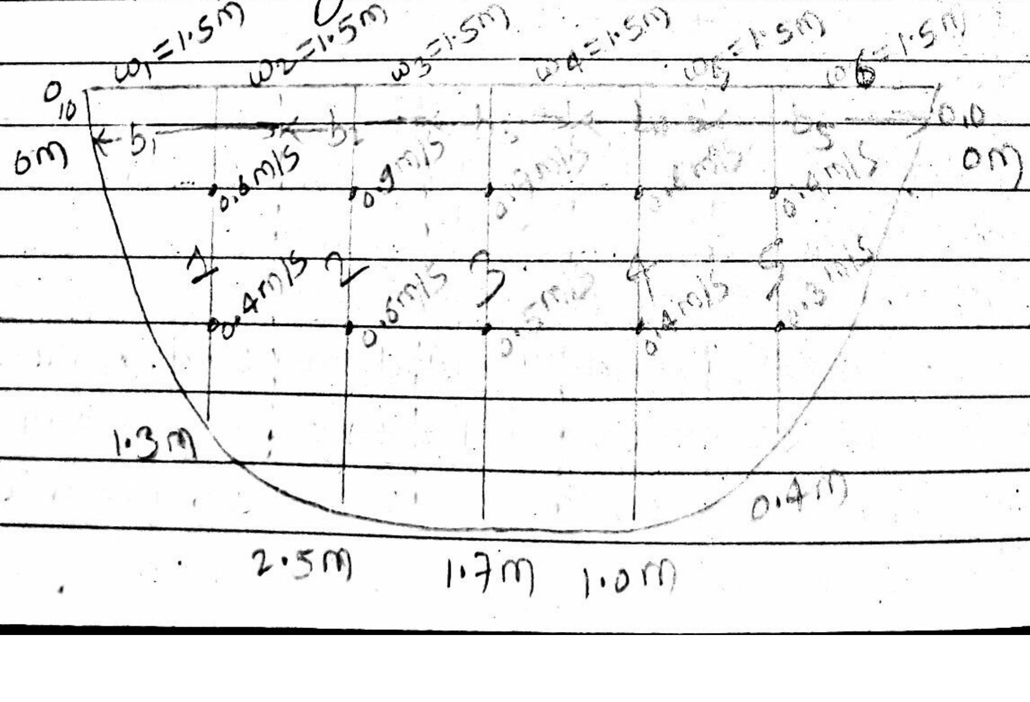
Hence, required discharge is $Q = 4.4415\ m^3/sec.$

5.4.1) The following data were collected during a stream-gauging operation in a river. compute the discharge.

Distance from left water edge (m)	depth (m)	velocity (m/s) at 0.2d	at 0.8d
0.0	0.0	0.0	0.0
1.5	1.3	0.6	0.4
3.0	2.5	0.9	0.6
4.5	1.7	0.7	0.5
6.0	1.0	0.6	0.4
7.5	0.4	0.4	0.3
9.0	0.0	0.0	0.0

Soln Doing by mid-section method

no. of segment = no. of depth = 5



Now, for the calculation of width

$$b_1 = \frac{(w_1 + w_2/2)^2}{2w_1} = \frac{(1.5 + 1.5/2)^2}{2 \times 1.5} = 1.6875 m$$

$$b_2 = w_2/2 + w_3/2 = 1.5/2 + 1.5/2 = 1.5 m$$

$$b_3 = w_3/2 + w_4/2 = 1.5/2 + 1.5/2 = 1.5 m$$

$$b_4 = w_4/2 + w_5/2 = 1.5/2 + 1.5/2 = 1.5 m$$

$$b_5 = \frac{(w_6 + w_5/2)^2}{2w_6} = \frac{(1.5 + 1.5/2)^2}{2 \times 1.5} = 1.6875 m$$

Then average velocities of each section is given by,

$$v_1 = v \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.6 + 0.4}{2} = 0.5 m/s.$$

$$v_2 = v \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.9 + 0.6}{2} = 0.75 m/s$$

$$v_3 = v \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.7 + 0.5}{2} = 0.6 m/s$$

$$v_4 = v \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.6 + 0.4}{2} = 0.5 m/s$$

$$v_5 = v \text{ at } \frac{0.2d + 0.8d}{2} = \frac{0.4 + 0.3}{2} = 0.35 m/s$$

& given average deths of each section is,

$d_1 = 1.3 m$

$d_2 = 2.5 m$

$d_3 = 1.7m$

$d_4 = 1.0\ m$

$d_5 = 0.4m$

So, calculating total discharge as the sum of discharges through each sections.

i.e $Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$

$= b_1 d_1 v_1 + b_2 d_2 v_2 + b_3 d_3 v_3 + b_4 d_4 v_4 + b_5 d_5 v_5$

$= 1.6875 \times 1.3 \times 0.5 + 1.5 \times 2.5 \times 0.75 + 1.5 \times 1.7 \times 0.6 +$
$1.5 \times 1.0 \times 0.5 + 1.6875 \times 0.4 \times 0.35$

$\therefore Q = 6.425625\ m^3/sec.$

Hence, required discharge is $6.425625\ m^3/sec.$

073 - 11 - 4 - wednesday.

S. 4.10) A small stream has a trapezoidal cross-section with base width of 12m and side slope 2 horizontal : 1 vertical in a reach of 8000m. During a flood the high water levels record at the ends of the reach are as follows.

section	elevation of bed (m)	water surface elevation (m)	Remarks
upstream	100.20	102.70	manning's $n = 0.030$
downstream	98.60	101.30	

Estimate the discharge in the stream.

Soln Using suffixes 1 & 2 to denote the upstream and downstream sections respectively, the cross-sectional properties are calculated as follows;

section 1	section 2
$z_1 = 100.20m$	$z_2 = 98.60m$
$h_1 = 102.70m$	$h_2 = 101.30m$
$\therefore y_1 = h_1 - z_1$	$\therefore y_2 = h_2 - z_2$
$= 102.70 - 100.20$	$= 101.30 - 98.60$
$= 2.5m$	$= 2.7m$
$A_1 = b_1 y_1 + z y_1^2$	$A_2 = b_2 y_2 + z y_2^2$
$= 12 \times 2.5 + 2 \times (2.5)^2$	$= 12 \times 2.7 + 2 \times (2.7)^2$
$= 42.5 m^2$	$= 46.98 m^2$
$P_1 = b_1 + 2y_1\sqrt{1+z^2}$	$P_2 = b_2 + 2y_2\sqrt{1+z^2}$
$= 12 + 2 \times 2.5\sqrt{1+4}$	$= 12 + 2 \times 2.7\sqrt{1+4}$
$= 23.1803 m$	$= 24.0748m$
$\therefore R_1 = \frac{A_1}{P_1} = \frac{42.5}{23.1803}$	$\therefore R_2 = \frac{A_2}{P_2} = \frac{46.98}{24.0748}$
$= 1.8334$	$= 1.9514m$

$K_1 = \frac{1}{n} R_1^{2/3} A_1$ $= \frac{1}{0.03} \times 42.5 \times (1.8334)^{2/3}$ $= 2122.1325$	$K_2 = 1/n \, A_2 R_2^{2/3}$ $= 1/0.03 \times 46.98 \times (1.9514)^{2/3}$ $= 2445.4341$

Average K for the reach, $K = \sqrt{K_1 K_2}$

$$= \sqrt{2122.1325 \times 2445.4341}$$

$$= 2278.0551$$

To start $h_f = h_1 - h_2 = 102.7 - 101.3 = 1.4\,m$ is assumed

Eddy loss $h_e = 0$ for uniform width.

The calculations are shown in table below.

$$\bar{S}_f = h_f/L = \frac{1.4}{8000} = 1.75 \times 10^{-4}\,m$$

$$Q = K\sqrt{\bar{S}_f} = 2278.0551\sqrt{1.75 \times 10^{-4}}$$

$$= 30.1358$$

$$\frac{V_1^2}{2g} = \left(\frac{Q}{42.5}\right)^2 \times \frac{1}{19.62}$$

$$\frac{V_2^2}{2g} = \left(\frac{Q}{46.98}\right)^2 \times \frac{1}{19.62}$$

$$h_f = (h_1 - h_2) + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - h_e$$

Trial	$\bar{h}_f$ (trial	$\bar{S}_f$ (10^{-4} m)	Q m^3/s.	$V_1^2/2g$ (m)	$V_2^2/2g$ (m)	h_f
1	1.4	1.75	30.1358	0.0256	0.0210	1.4046
2	1.4046	1.75575	30.1853	0.0257	0.0210	1.4047
3	1.4047	1.7559	30.1864	0.0257	0.0210	1.4047

Since the value of hf is found same so we stop trial.
& The discharge in the channel is $Q = \underline{\underline{30.1864\ m^3/s}}$.

Q During a flood flow the depth of water in a 10m wide rectangular channel was found to be 3.0m & 2.9m at two sections 200m apart. The drop in the water-surface elevation was found to be 0.12m. Assuming Manning's coefficient to be 0.025, estimate the flood discharge through the channel.

Sol^n Using suffixes 1 & 2 to denote the upstream & downstream sections respectively, the cross-sectional properties are calculated as follows.

Section 1	Section 2
$b_1 = b = 10m$	$b_2 = b = 10m$
$d_1 = 3.0m$	$d_2 = 2.9m$
$\therefore A_1 = b_1 d_1 = 10\times3$	$\therefore A_2 = b_2 d_2$
$= 30m^2$	$= 10\times2.9 = 29m^2$
$P_1 = b_1 + 2d_1$	$P_2 = b_2 + 2d_2$
$= 10 + 2\times3$	$= 10 + 2\times2.9$
$= 16m$	$= 15.8m$
$R_1 = \frac{A_1}{P_1} = \frac{30}{16} = 1.875m$	$R_2 = \frac{A_2}{P_2} = \frac{29}{15.8} = 1.8354m$
$K_1 = \frac{1}{n} A_1 R_1^{2/3}$	$K_2 = \frac{1}{n} A_2 R_2^{2/3}$
$= \frac{1}{0.025} \times (30) \times (1.875)^{2/3}$	$= \frac{1}{0.025} \times (29) \times (1.8354)^{2/3}$
$= 1824.6606$	$= 1738.9155$

Average K for the reach, $K = \sqrt{K_1 K_2}$

$= \sqrt{1824.6606 \times 1738.9155}$

$= 1781.2722$

To start, $h_f = h_1 - h_2 = 0.12\,m$ (given)

length $(L) = 200m$ (given)

Eddy loss $h_e = 0$, for $K_e = 0$ (uniform width)

The calculations are shown in table below,

$$\bar{S}_f = \frac{h_f}{L} = \frac{0.12}{200} = 6 \times 10^{-4} m$$

$$Q = K\sqrt{\bar{S}_f} = 1781.2722\sqrt{6 \times 10^{-4}}$$

$$= 43.6321$$

$$\frac{V_1^2}{2g} = \left(\frac{Q}{30}\right)^2 \times \frac{1}{19.62}$$

$$\frac{V_2^2}{2g} = \left(\frac{Q}{29}\right)^2 \times \frac{1}{19.62}$$

$$h_f = 0.12 + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - h_e$$

Trial	h_f (trial)	$\bar{S}_f$ (10^{-4}m)	Q (m^3/s)	$V_1^2/2g$ (m)	$V_2^2/2g$ (m)	h_f
1	0.12	6.0	43.6321	0.1078	0.1154	0.1124
2	0.1124	5.62	42.2278	0.1010	0.1081	0.1129
3	0.1129	5.645	42.3216	0.1014	0.1085	0.1129

since the value of h_f is found same so we stop trial.
& The discharge in the channel is $Q = 42.3216\ m^3/s$

Estimation of missing data (Numericals).

Q) The normal annual rainfall at stations A, B, C and D in a basin are 80.97 cm, 67.59 cm, 76.28 cm and 92.01 cm respectively. In the year 1975, the station D was inoperative and the stations A, B & C recorded annual precipitation of 91.11 cm, 72.23 cm & 79.89 cm respectively. Estimate the rainfall at station D in that year.

Sol^n Given,

Normal annual rainfall at station A, $N_A = 80.97$ cm
Normal annual rainfall at station B, $N_B = 67.59$ cm
Normal annual rainfall at station C, $N_C = 76.28$ cm
Normal annual rainfall at station D, $N_D = 92.01$ cm
& Annual precipitation at station A, $P_A = 91.11$ cm
Annual precipitation at station B, $P_B = 72.23$ cm
Annual precipitation at station C, $P_C = 79.89$ cm
Annual precipitation at station D, $P_D = ?$

Now,

check

$$\frac{N_D - N_A}{N_A} \times 100\% = \frac{92.01 - 80.97}{92.01} \times 100\%$$

$$= 11.99\%$$

Since, normal annual rainfall of station A exceed 10% of the normal annual rainfall of station D so, we use normal ratio method.

i.e $$P_D = \frac{N_D}{N-1}\left[\frac{P_A}{N_A} + \frac{P_B}{N_B} + \frac{P_C}{N_C}\right]$$

$$\text{or, } P_D = \frac{92.01}{4-1}\left[\frac{91.11}{80.97} + \frac{72.23}{67.59} + \frac{79.89}{76.28}\right]$$

$$\therefore P_D = 99.41 \text{ cm}$$

Hence, Annual precipitation at station D, $P_D = \underline{\underline{99.41 \text{ cm}}}$.

Q) S. 53.(2.7)) For a drainage basin of 600 km^2, isohyetals drawn from a strom gave the following data.

Isohyetals (interval) cm	15 - 12	12 - 9	9 - 6	6 - 3	3 - 1
Inter - isohyetal area (km^2)	92	128	120	175	85

Estimate the average depth of precipitation over the catchment.

soln Given information are tabulated as,

Isohyetals (interval) (cm)	Average value of P (cm)	Area, A (km^2)	A x P ($cm \cdot km^2$).
15 - 12	13.5	92	1242
12 - 9	10.5	128	1344
9 - 6	7.5	120	900
6 - 3	4.5	175	787.5
3 - 1	2.0	85	170
Total		600	~~4083.5~~
			4443.5

So, Average depth of precipitation $(\bar{P}) = \frac{\Sigma A_n P_n}{\Sigma A_n}$

$= \frac{4443.5 \; \cancel{4083.5}}{600}$

~~$\therefore \bar{P} = 6.80 cm$~~

$\therefore \bar{P} = 7.41 cm$

Hence, the average depth of precipitation over the catchment is found to be, $\bar{P} = 7.41$ cm.

8) A reservoir had an average surface area of $20 km^2$ during june 2003. In that month the mean rate of inflow = $10 m^3/s$, outflow = $15 m^3/s$, monthly rainfall = 10 cm & change in storage $16 \times 10^6 m^3$. Assuming the seepage losses to be 1.8cm, estimate the evaporation in that month.

Soln Given, Area (A) = $20 km^2 \times = 20 \times 10^6 m^2$

$$\text{Inflow (I)} = 10 m^3/s \times 30 \times 24 \times 3600 \text{ sec}$$
$$= 25.92 \times 10^6 m^3$$

or, $I = \frac{25.92 \times 10^6 m^3}{20 \times 10^6 m^2} = 1.296 m = 129.6 cm$

$$\text{outflow (O)} = 15 m^3/s \times 30 \times 24 \times 3600 \text{ sec}$$
$$= 38.88 \times 10^6 m^3$$

or, Out $= \frac{38.88 \times 10^6 m^3}{20 \times 10^6 m^2} = 1.944 m = 194.4 cm$

rainfall (P) = 10 cm

change in storage (ΔS) = $16 \times 10^6 m^3$

i.e $\frac{16 \times 10^6 m^3}{20 \times 10^6 m}$

$= 0.8 m$

$= 80 cm$

seepage losses = 1.8 cm

evaporation (E) = ?

Now, we have,

$$\Delta S = P + I - O - \text{seepage} - \text{evaporation}$$

or, evaporation (E) = P + I − Out − seepage − ΔS

$$= 10 + 129.6 - 194.4 - (-80)$$

or, $E = 10 + 129.6 - 194.4 + 80$

$\therefore E = 25.2 cm$

Hence evaporation in that month is $(E) = 25.2 cm$.